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Argonne National Laboratory

PHYSICS DIVISION SUMMARY REPORT

July-August 1963

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Physics
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois
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PHYSICS DIVISION SUMMARY REPORT

July-August 1963

Lowell M. Bollinger, Division Director

Preceding Summary Reports:

ANL-6679, January-February 1963
ANL-6719, March-May 1963
ANL-6720, June 1963

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FOREWORD

The Argonne National Laboratory Physics Division Summary Report is issued almost monthly for the information of the members of the Division and a limited number of other persons interested in the progress of the work.

Since reports on any particular research program are written at irregular intervals, the individual issues usually present only a fragmentary picture of the work of the Division. To counteract this, the active projects not reporting are listed in each issue; and an Annual Review issue presents a comprehensive survey.

The articles in the Physics Summary are informal progress reports. The results and data therefore must be understood to be preliminary, tentative, and often incomplete.

The issuance of these reports is not intended to constitute publication in any sense of the word. Final results either will be submitted for publication in regular professional journals or, in special cases, will be presented in ANL Topical Reports.

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I-3. Cross-Section Measurements with the Fast Neutron Velocity Selector (ANL-6534, April-May 1962), L. M. Bollinger, R. E. Coté, H. E. Jackson, J. P. Marion, and G. E. Thomas.

I-6. Double Isomerism in As^{73} (ANL-6719, March-May 1963), H. H. Bolotin.

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I-14. Pulsed-Beam Experiments with the Van de Graaff Machine (ANL-6679, January-February 1963), F. J. Lynch, and E. N. Shipley.

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IV. PLASMA PHYSICS

V. THEORETICAL PHYSICS, GENERAL

I. EXPERIMENTAL NUCLEAR PHYSICS

I-10-3 Tandem Van de Graaff Accelerator (51210-01)

J. R. Wallace

This report covers the operation of the tandem Van de Graaff during the period of February 1963 to July 31, 1963.

The experimental demands for time on the tandem have steadily increased. A 5-day/week schedule (24 hr/day) has been in operation from February until July. An additional 16 hrs of operation has been added on Saturday. Plans have been made for a seven-day (24 hr/day) operation as soon as additional manpower can be recruited and trained.

It appears that the installation of freon-cooled refrigeration baffles in the main pumping stations will greatly lengthen the operating period of the mercury diffusion pumps. Steps are being taken to have such baffles made and to purchase small refrigeration systems to be used with them. The loss of mercury from the diffusion pumps to the liquid N_2 trap has required monthly attention since the Tandem was put into operation.

A beam buncher and pulser has been added to the Tandem. Frank Lynch has coordinated the installation of this equipment, which Central Shops and the Electronics Division have built under his direction.

The installation of the broad-range magnetic spectrograph is almost completed, and John Erskine is making preliminary runs with it.

The heavy-ion program on the Tandem is underway. An oscillator circuit capable of higher power for use with an rf ion source has been designed by Albert Hatch and Arthur Froehlich. This circuit is now under construction. Robert Holland has been directing these heavy-ion investigations and the required modifications of the control circuits necessary for this program.

Some problems have been encountered in the duoplasma ion source during this period of operation, but the major portion of the Tandem has been trouble-free. This has resulted in 2275 hours of operation (February 1 — July 31, 1963).

I-11-31 Operation of the 4.5-MeV Van de Graaff Generator (51210-01)

J. R. Wallace

This report summarizes the changes that have been made on the 4.5-MeV Van de Graaff generator of the Physics Division.

There has been a long-range program for some time to improve energy stability and to increase the beam intensity at the target of this machine. These are needed for certain scattering experiments. Alexander Langsdorf, Jr., one of the prospective beneficiaries of the improvements, has been devoting a great deal of his time to accomplish these objectives.

The changes that have been made include (1) an entirely new belt-charging system; (2) a new oscillator circuit (which delivers more power to the rf ion source); (3) several new power supplies (for the focus supply, belt-charging system, etc.); (4) modifications inside the generator so that the two large voltage-dividing shells could be removed; (5) modifications of the energy-control circuits; (6) an improved tensioner assembly for the charging belt; and (7) new 400-cps generators for ion-source power.

These changes have made it possible to operate the generator at lower voltages with larger beam currents. The lifetime of the charging belt has been greatly increased. Beam currents at higher voltages have been increased.

Removal of the large voltage-dividing shells now allows relocation of the generator so that a beam-steering system can be installed between the machine and the switching magnet. This will greatly reduce experimental setup time and facilitate the rechecking of results during an experiment with the Van de Graaff.

The Electronics Division is now designing and building an improved power supply for the electrostatic analyzer and also power supplies and controls for the beam-steering system to be installed in the near future.

An improved target design will also be required to handle the increased beam currents.

Further details of these changes will be available in later reports. Progress has been slow because modifications are added piecemeal to avoid interrupting the experimental programs.

I-18-17 Neutron Polarization and Differential Cross Sections (51210-01)

R. O. Lane, A. J. Elwyn, and A. Langsdorf, Jr.

POLARIZATION OF NEUTRONS SCATTERED FROM Be^9: PARITIES OF 7.37- AND7.54-MEV STATES IN Be^{10}

The polarization $P(\theta)$ and differential cross section $\sigma(\theta)$ for neutrons scattered from Be^9 were measured at 5 angles for incident neutron energies from 0.2 to 2.0 MeV. The source of partially polarized neutrons was the $Li^7(p,n)Be^7$ reaction with neutrons emitted at 51° with respect to the incident proton beam. Polarization was measured by determining the difference between the scattered intensity without a magnetic field and the intensity when the neutrons incident on the scatterer were passed through the transverse field of an electromagnet set to precess the spins through 180°. A more detailed description of the equipment and method can be found elsewhere.[1] Figures 1 and 2

[1] R. O. Lane, A. J. Elwyn, and A. Langsdorf, Jr., Phys. Rev. 126, 1105 (1962); A. J. Elwyn, R. O. Lane, and A. Langsdorf, Jr., Phys. Rev. 128, 779 (1962).

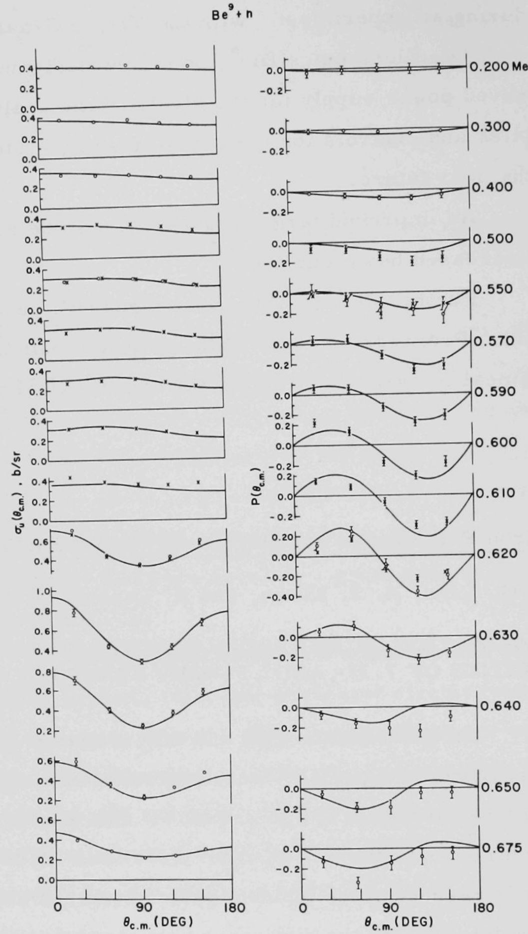

Fig. 1. Angular distributions of the differential scattering cross sections $\sigma_u(\theta_{c.m.})$ and the polarization $P(\theta_{c.m.})$ in the center-of-mass system for $Be^9 + n$. Neutron energies in the laboratory system (0.200 — 0.675 MeV) appear on the right. Circles and crosses are experimental points for scatterers $\frac{1}{16}$ in. and $\frac{1}{8}$ in. thick, respectively. Where no error bars appear, errors are less than the size of the points. The curves were calculated from the final set of parameters shown in Table I and averaged over the energy spread of the beam.

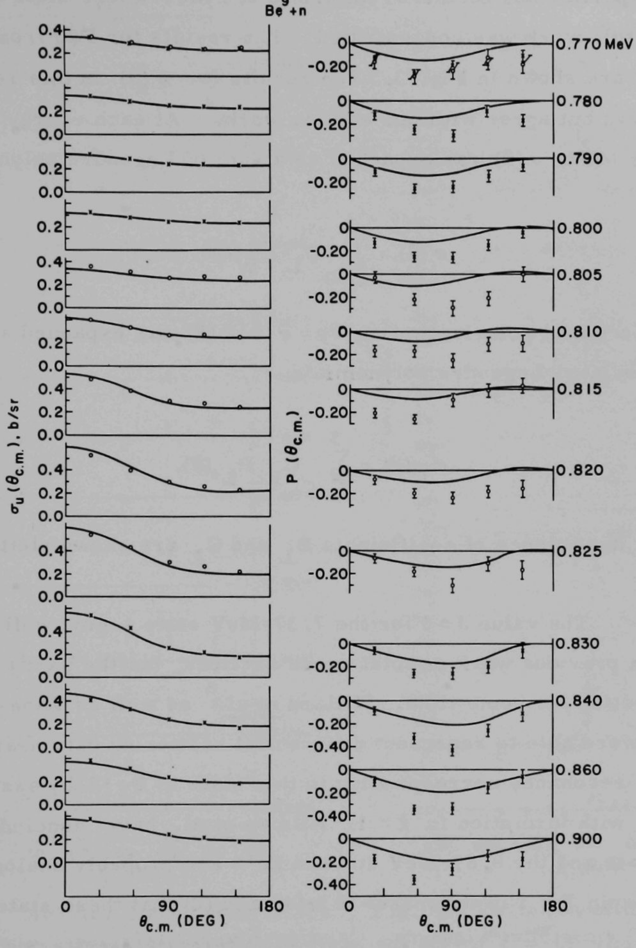

Fig. 2. Angular distributions of the differential scattering cross sections $\sigma_u(\theta_{c.m.})$ and the polarization $P(\theta_{c.m.})$ in the center-of-mass system for $Be^9 + n$. Neutron energies in the laboratory system (0.770 — 0.900 MeV) appear on the right. Circles and crosses are experimental points for scatterers $\frac{1}{16}$ in. and $\frac{1}{8}$ in. thick, respectively. Where no error bars appear, errors are less than the size of the points. The curves were calculated from the final set of parameters shown in Table I and averaged over the energy spread of the beam.

show the experimental results from 0.2 to 0.9 MeV where most of the interest in this work was concentrated. The results for $P(\theta)$ from 1.0 to 2.0 MeV are shown in Fig. 3. The results for $\sigma(\theta)$ in this region are not shown but agree with our earlier work.[2] At each energy between 0.2 and 0.9 MeV, $\sigma(\theta)$ was expanded as a sum of Legendre polynomials

$$\sigma(\theta) = \sum_{L=0}^{3} B_L P_L(\theta) ,$$

and the differential polarization $\sigma_P(\theta) = \sigma(\theta)P(\theta)$ was expanded as a sum of associated Legendre polynomials

$$\sigma_P(\theta) = \sum_{L=1}^{3} C_L P_L'(\theta).$$

The energy dependence of coefficients B_L and C_L are shown plotted in Figs. 4-6.

The value J = 3 for the 7.37-MeV state seems well established from previous work on total cross sections, but the parity has been in question for some time. Willard *et al.*[3] as well as Lane and Monahan[4] were able to represent differential scattering data near the 0.625-MeV resonance corresponding to this state in Be^{10} by assuming $J^{\pi} = 3^{+}$ with formation in $\ell = 1$. Altman *et al.*[5] have concluded (1) that this state and the 8.89-MeV state in Be^{10} are probably analog states of isotopic spin T = 1 in the mass-10 triad and (2) that these states have negative parity ($J^{\pi} = 3^{-}$). On the basis of differential-scattering work

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[2] R. O. Lane, A. Langsdorf, Jr., J. E. Monahan, and A. J. Elwyn, Ann. Phys. 12, 135 (1961).

[3] H. B. Willard, J. K. Bair, and J. D. Kington, Phys. Rev. 98, 669 (1955).

[4] R. O. Lane and J. E. Monahan, Bull. Am. Phys. Soc. 1, 187 (1956).

[5] A. Altman, W. M. MacDonald, and J. B. Marion, Nucl. Phys. 35, 85 (1962).

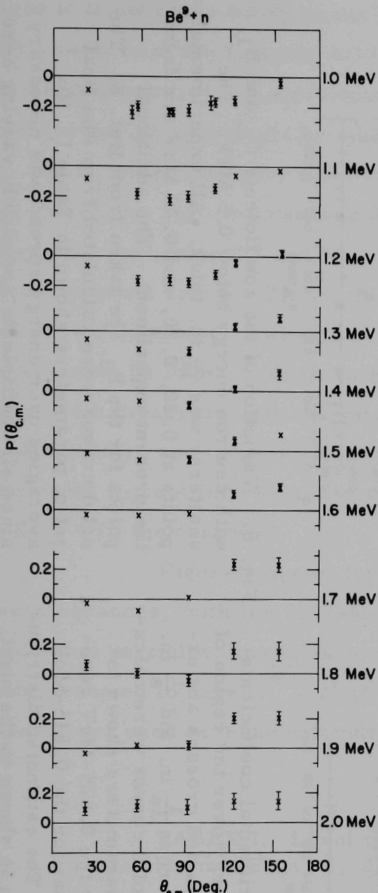

Fig. 3. Angular distribution of the measured polarization of neutrons scattered from Be^9 for neutron energies of 1.0 — 2.0 MeV.

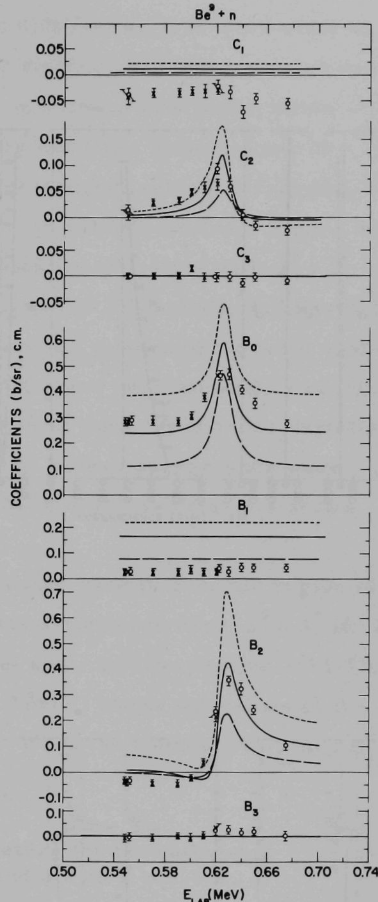

Fig. 4. Variation of the experimental coefficients C_L and B_L with neutron energy across the 0.625-MeV resonance as compared with the curves calculated for different values of the nuclear radius R. Circles are the experimental values for scatterers $\frac{1}{16}$ in. thick, crosses for a thickness of $\frac{1}{8}$ in. Curves are calculated for the assignment $3^+(\ell = 1,\ S = 2$ only) for the state. The dashed curves are for R = 5.6 F, the solid curves for R = 8 F, and the dotted curves for R = 10 F.

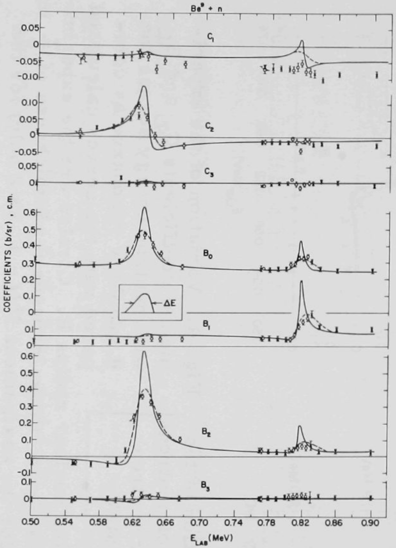

Fig. 5. Variation of the experimental coefficients C_L and B_L with neutron energy over the region of the two resonances. Circles and crosses are experimental values for scatterers $\frac{1}{16}$ in. and $\frac{1}{8}$ in. thick, respectively. The solid curves were calculated from the final set of parameters shown in Table I, the assignment for the 0.625-MeV resonance being $3^-(\ell = 2)$ and that for the 0.815-MeV resonance being $2^+(\ell = 1)$. The estimated distribution of energies in the beam is shown in the inset. Dashed curves were obtained by averaging the calculated curves over the energy distribution of the beam.

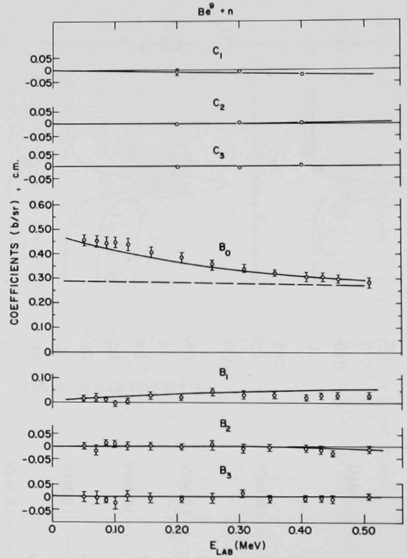

Fig. 6. Variation of the coefficients C_L and B_L with neutron energy below 0.5 MeV. The scatterer was $\frac{1}{16}$ in. thick. All experimental points at 0.20, 0.30, and 0.40 MeV are from the present experiment. The additional points for the B_L are taken from Ref. 8. The solid curves were calculated from the final set of parameters shown in Table I. No averaging over energy spread was necessary since all coefficients are slowly varying here. The dashed curve in B_0 is calculated without considering any effects of bound states.

alone it is not clear which parity is correct for the 7.37-MeV state in B^{10}, because of the freedom allowed in making assumptions which are not readily verified. It was hoped that with these new polarization data the assignment might be made more definite. Calculations of C_L and B_L were made for a two-channel (channel spins S = 1, 2) process whenever this process was allowed by selection rules. Figure 4 shows the best fit to C_L and B_L calculated for this state with $J^\pi = 3^+$ ($\ell = 1$), channel spin S = 2 only, for radii of 5.6 F (dashed), 8.0 F (solid), and 10.0 F (dotted). For this assignment all s-wave background scattering must be in S = 1 (because B_1 and C_1 are nonresonant), a conclusion which disagrees with thermal scattering data. Numerous variations in parameters and contributions of s- and p-wave backgrounds were attempted without improving the fits. None of the calculations shown in Fig. 4 fit the data well.

Figure 5 shows the calculated results over the region of the two resonances, with the 7.37-MeV state assumed to have $J^\pi = 3^-$ ($\ell = 2$) with equal partial widths in each channel spin, and the narrow 7.54-MeV state assumed to have $J^\pi = 2^+$ ($\ell = 1$). Table I shows the values of the parameters used in these calculations. When the calculated C_L and B_L

TABLE I. Level parameters for the calculated curves shown in Figs. 1, 2, 5, and 6 with R = 5.6 F.

E_r (MeV, lab)	J^π	ℓ	$\mathcal{E}$ (MeV, c.m.)	γ_n^2 (MeV, c.m.) S = 1	S = 2	$\Gamma_n(E_r)$ (MeV, lab) S = 1	S = 2	θ^2
0.625	3^-	2	0.287	0.082	0.082	0.008	0.008	0.075
0.815	2^+	1	0.732	0.0008	0.0053	0.0008	0.0053	0.0028

are averaged (dashed curves) over the energy spread ΔE of the neutron beam, the agreement with the dominant resonant coefficients for the data is quite good and is strong evidence for the latter assignment for these levels. The reasons for the systematic discrepancies in the non-resonant coefficient C_1 above 0.6 MeV and in B_1 below 0.7 MeV are not clear. However, of primary importance in determining the assignments here is the fact that the dominant resonant terms are in good agreement with the data. For these final calculations, the bound 1^- and 2^- states in Be^{10} were included in the s-wave background and accounted well for the sharp rise in σ_T at low energies, as can be seen in Fig. 6 where the calculated results are compared with the data below 0.5 MeV. The p-wave background included was that for J = 3; all others lead to further disagreement with the data, e.g., the wrong sign for C_1.

It can be concluded directly from this interpretation of these experimental data that J^{π} is most probably 3^- (ℓ = 2) for the 7.37-MeV state in Be^{10} and 2^+ (ℓ =1) for the 7.54-MeV state.

A more detailed account of this work is being submitted to the Physical Review.

I-38-1 Computer Program for Analysis of Complex Continuous Beta-Ray Spectra (51210-01)

S. B. Burson, R. G. Helmer, and T. Gedayloo

INTRODUCTION

In collaboration with W. J. Cody and J. A. Gregory of the Argonne Applied Mathematics Division, a two-stage computer program (for the IBM-704) has been developed for the analysis of complex beta-ray spectra. Only the second stage will be described. The first stage accomplishes standard data reduction.

A spectrum comprising as many as thirteen components can be analyzed. Each component is presumed to consist of a linear combination of allowed and unique-first-forbidden transitions and is represented by three parameters: the slope m of its Fermi plot (related to relative intensity), the end-point energy ϵ_0, and the "shape-partition factor" α. Before the calculation, initial estimates must be made for all parameters of the components assumed to be present.

The free, or unfixed, parameters are varied simultaneously in order to minimize the function

$$\chi^2 = \sum_i w_i \left[N_i - \overline{N}_i(p_j)\right]^2 ,$$

where N_i and $\overline{N}_i(p_j)$ are the experimental and calculated counting rates, and w_i is the weight factor.

There are seventeen options that must be exercised by the user before any calculation is made. Four of these are expressed by means of sense switches; the remaining thirteen are indicated through the choice of control constants punched on the control card that represents the calculation. The program will process up to 400 data points. The computer for which the program was designed has a storage capacity of 32 000 words and the running time has averaged 5 — 10 min. The program was compiled by use of FORTRAN and is on punched cards. The input and output data are on magnetic tape except in the case of optional on-line printing by means of sense switch 3.

ANALYSIS

In this program, the method of iterated least-squares fitting is applied to an experimentally measured beta-ray spectrum. The approach has the distinct advantage that it is possible to quantitatively separate beta components whose end points are quite close together. This circumstance often renders the conventional "peeling" procedure extremely difficult if not entirely impossible. However, the options of the program are designed to retain all of the flexibility that accompanies manual analysis.

The substance of the least-squares procedure is to assume some analytic function that is believed to represent the experimental observations and then adjust the parameters of this function until the best fit is obtained. The word "best fit" is used in a statistical sense.

A simplifying assumption is made in this program, which (although false in detail) makes it possible to write an analytic expression that can represent a very large class of beta-ray spectra. The assumption is that any single component has either an allowed shape or a unique first-forbidden shape, or (more generally) that it can be represented by a linear combination of these two shapes.

The expression used to represent the allowed shape is

$$N(\eta) = m^2 f(Z,\eta)\,(\epsilon_0 - \epsilon)^2 L_0(\eta), \qquad \text{(allowed)} \qquad (1)$$

where η is the momentum of the beta, $\epsilon^2 = \eta^2 + 1$, $m^2 =$ (Const.) $g^2 M^2$, $f(Z,\eta) = \eta^2 F(Z,\eta)_{\text{screened}}$, and $L_0(\eta)$ is the shape factor. The expression holds to a very close approximation for transitions of either allowed or ordinary-first-forbidden character. The Fermi plots of these spectra are linear to within a few percent. In Eq. (1), the counting rate $N(\eta)$ is expressed as a function of the energy ϵ. The parameter m combines the intensity scale factor, related to instrumental transmission and source strength, with the nuclear matrix element. This is one of the parameters that must be adjusted in order to make the expression match the data.

The Fermi factor f is the product of the square of the momentum η and the true Fermi function F. The Fermi functions are not interpolated, but are computed directly by means of a subroutine based on the screened Fermi function

$$F = \frac{2}{\pi^3}\,(2R)^{2S}\left[\frac{1}{\Gamma(3+2S)}\right]^2\left[\frac{\epsilon_V\,\eta_V}{\epsilon\,\eta}\right]\eta_V^{\,2S}\left[\Gamma(1+S+i\delta_V)\right]^2 e^{\pm\pi\delta_V}, \qquad (2)$$

where R is the nuclear radius, $S = (1 - \alpha^2 Z^2)^{1/2} - 1$,

$\delta_V = \alpha Z \epsilon_V/\eta_V$, $\epsilon_V = \epsilon \mp V_0$, $V_0 = [30.9/(5.11 \times 10^5)]Z^{4/3}$. The shape correction factor L_0 is derived by interpolation from a table that must be read into the computer at the beginning of the analysis.

For a single component of allowed shape, it is sufficient to determine the best values of the two parameters, m and the end-point energy ϵ_0.

The expression used to represent a component having unique-first-forbidden shape (that is, $\Delta I = 2$ with a change of parity) is

$$N(\eta) = m^2 f(Z, \eta)(\epsilon_0 - \epsilon)^2 \frac{1}{12}[(\epsilon_0 - \epsilon)^2 L_0 + 9L_1], \quad \text{(unique)}$$

where $m^2 = (\text{Const.})\, g^2 M^2$. The terms in the expression have the same meanings as before and again there are only two adjustable parameters.

If one now assumes that a single component comprises contributions from two transitions, one with allowed shape and one with unique shape, the distribution can be represented by

$$\overline{N}_j = m_j^2 f(\epsilon_{0_j} - \epsilon)^2 \ \{(1 - a_j)L_0 + \frac{a}{12} j \ [(\epsilon_{0_j} - \epsilon)^2 L_0 + 9L_1]\} .$$

The end-point energy is still a well-defined parameter. However, the slope m may take on a somewhat obscure meaning. It would not, of course, be physically meaningful to factor out two different matrix elements and combine them into a single coefficient. It is necessary to introduce a new variable parameter a that expresses the relative partition of the spectrum into the two different shapes. A single component is thus described by these three parameters.

In general, the beta spectrum will comprise a number of components with various end-point energies. If the presence of J such components is assumed, the distribution is

$$\overline{N} = \sum_{j=1}^{J} \overline{N}_j(m_j^2, \epsilon_{0_j}, a_j).$$

To describe any complex spectrum comprising J components, there are 3J parameters to be adjusted. This is the equation that is used in the program to calculate the theoretical counting rate to be compared with the data. The best values of these 3J parameters are to be determined by a least-squares procedure.

The calculation to determine the best values of the parameters that define the experimental spectrum minimizes the function

$$\chi^2 = \sum_i w_i \left[N_i - \overline{N}_i(p_j)\right]^2,$$

where N_i is the experimental and $\overline{N}_i(p_j)$ the calculated count, by setting $\partial\chi^2/\partial p_j = 0$ simultaneously for all values of j. This calculation cannot be done explicitly unless the analytic function used to fit the data is linear in the variables, so the expression for $\overline{N}$ is expanded in a Taylor series. This approximation then requires that original estimates be provided for all of the variable parameters. These original estimates correspond to the point about which the expansion is being made. The results of the first calculation are then fed back into the equation as input estimates and the calculation is repeated. This iterative procedure constitutes a series of successive approximations which, it is hoped, will converge upon the desired best values of the parameters. In addition to providing original estimates for all of the variable parameters, it is necessary to specify some criterion of convergence in order to know when to stop the calculation. This condition is specified by the expression $|\Delta p_j / p_j| < \delta$. The calculation is terminated when the condition is simultaneously satisfied for all of the parameters, that is, when the relative change becomes less than some specified number.

OPTIONS

Seventeen options must be exercised in order to specify the details of each calculation. These are referred to as INPUT OPTIONS. Thirteen of the decisions are indicated by numbers punched on a control card; the remaining four are indicated by the positions of four sense switches on the computer. Many of the constants are of a purely procedural nature and will be mentioned only briefly.

(1) The first constant indicates where the experimental data are to be found and the form in which they are tabulated. Original input data are always on magnetic tape.

(2) The tables of shape factors, which are always needed, are taken from the compilation by Rose et al.[1]

(3) The user has the option of using the statistical weights (option 1) or not (option 0).

(4) The program will accommodate up to 400 data points. The least-squares fit can be made to any desired region of the spectrum. As many as nineteen groups of adjacent points can be by-passed and excluded from the calculation.

(5) If the data have already been partly analyzed and one or more of the components have already been determined with certainty, these components can be subtracted from the data before proceeding to the least-squares fit. Up to thirteen such components can be subtracted.

(6) The iterated least-squares procedure requires one to have some knowledge of the composition of the spectrum, or at least to be able to make an educated guess. A positive value of this control constant indicates the number of components that are expected to be present in the region of the spectrum that is being fitted. If the choice -1 is used,

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[1] M. E. Rose, C. L. Perry, and N. M. Dismuke, Tables for the Analysis of Allowed and Forbidden Beta Transitions, Oak Ridge National Laboratory Report ORNL-1459.

the final values of the parameters that were calculated in the previous fit will be used as input estimates. This freedom makes it possible to invoke a wide variety of analytical approaches to the same data.

(7) Any of the parameters can be held fixed at their input values and then released during successive fits after the computer has improved the values of those that are allowed to vary.

(8) In many cases the difference in energy between two end points will be known exactly from scintillation experiments, measurements on internal-conversion electrons, or Coulomb excitation. This knowledge can be incorporated into the calculation in the form of a "related end-point" system. Both end points will be allowed to vary simultaneously; but the difference in energy will remain fixed. Up to six such systems of related end points can be included in the calculation with as many as eleven end points being combined into a single system.

(9) The value of χ^2, which is used as a measure of the goodness of the fit, is computed only for the data points that were not by-passed. It is also possible to partition the spectrum into groups of data points and compute the partial χ^2 for each group. This device can sometimes give a clue as to why and where the fit is not good.

(10) The tenth control constant limits the number of times (≤ 100) the computer will try to make the fit. The upper limit on the number of iterations is specified and if the calculation does not converge in that many iterations, the machine will stop and await further instructions. If the series of calculations does converge, the results are printed out automatically and the next control card is read without interruption.

(11) There are two ways of calculating the errors propagated through a subtraction. One of these utilizes the off-diagonal elements of the inverse matrix that is calculated during the least-squares fit. These off-diagonal terms relate to the correlation between the

parameters. The simpler formula uses only the diagonal elements which can be computed without the matrix. Either formula can be invoked if the subtraction is to be carried out after a fit has been made, since the matrix is still present in the machine. However, in the case of pre-subtraction, there is no choice; only the diagonal elements can be used.

(12) This constant specifies whether or not the components that were calculated should be subtracted before the next fit is commenced. If they are subtracted, the propagated error is calculated according to the formula that was selected by the previous control constant, and the residual spectrum is written into the memory unit in place of the original data.

(13) The last control constant indicates how much of the information that was calculated should be printed on the output tape that is used on the off-line printer.

SENSE SWITCHES

(1) Sense switch 1 is used to frustrate the iterative procedure. It accomplishes this by automatically setting all of the computed parameter changes to zero.

(2) Sense switch 2 is used when the machine fails to converge. If the number of iterations reaches the limit and the machine stops, a second attempt to reach convergence on the same set of input information can be instituted by pressing the start button. If it is decided to abandon that particular calculation, sense switch 2 is put down and the start switch is then pressed. This causes the computer to advance to the next control card and continue in the series of programmed calculations.

(3) Sense switch 3 permits on-line printing of a very limited amount of information. With sense switch 3 down, the interim values of the parameters are printed on-line after each interation.

(4) Sense switch 4 provides a limited control over the mechanism of the least-squares fit itself. Each iteration results in a calculated group of correction terms that are added to each of the variable parameters before the next matrix is set up. If the amount by which each of the parameters is allowed to step is reduced, the rate at which the series converges is reduced. However, this reduction also has the effect of damping oscillations that may result when any of the corrections are too large.

A complete report on this program is being prepared as Argonne National Laboratory topical report ANL-6704.

I-80-32 Molecular-Beam Studies (51210-01)

William Childs, John Dalman, and Leonard Goodman
Reported by William Childs

Since the last report, a great deal of effort has gone into further work on radioactive Cr^{51}. The principal sources of trouble have been the difficulty of producing, day after day, a steady atomic beam of chromium, and the poor signal-to-noise ratios observed except under ideal conditions. Although the $\Delta F = \pm 1$ transitions have not been observed directly, study of the $\Delta F = 0$ transitions leads to the result

$$|a(Cr^{51})| = 81.2 \pm 0.2 \text{ Mc/sec}$$

for the magnetic-dipole hyperfine-interaction constant.

A greatly improved electron-bombardment universal detector has been installed in the Mark II atomic-beam machine. The counting circuitry, although somewhat refined, is basically the same as that described previously.[1] Perhaps the most important improvement

[1] Argonne National Laboratory Physics Division Summary Report ANL-6612 (September-October 1962), p. 3.

in the detector itself is the provision for maintaining the ion box of the detector at liquid nitrogen temperature. This greatly reduces the number of background ions not associated with the beam. Other important improvements are greatly increased mass resolution, increased efficiency both for extraction of the ions from the ionization region and in guiding them to the electron multiplier detector, and a threefold increase in the maximum ion counting rate which can be handled (now 4×10^7 ions/sec).

The Mark II machine, together with its new universal detector, has been successfully used for a complete investigation of the hfs of Cr^{53} in its $^7S_3$ atomic ground state. The result for the magnetic-dipole hyperfine-interaction constant a is

$$|a(Cr^{53})| = 82.5985 \pm 0.0015 \text{ Mc/sec.}$$

The electric-quadrupole hyperfine-interaction constant b is found to be consistent with 0, the value expected for a pure $^7S_3$ atomic state, to within the accuracy of the experiment. A paper describing the experiment and its results has been written and will be submitted to the Physical Review.

Since the nuclear g factor for Cr^{53} is known, the g factor for Cr^{51} can be estimated from the Fermi-Segrè proportionality. Thus we have

$$|g_I(Cr^{51})| = \left| g_I(Cr^{53}) \cdot \frac{a(Cr^{51})}{a(Cr^{53})} \right| .$$

From this and the known nuclear spin I of Cr^{51}, we have

$$|\mu_I(Cr^{51})| = 1.09 \pm 0.01 \text{ nm,}$$

where the uncertainty results primarily from the possibility of a hyperfine anomaly between the two isotopes Cr^{51} and Cr^{53}.

From the numbers given above, the magnetic field H_J which the electronic configuration produces at the chromium nucleus is calculated to be

$$H_J(Cr^{51,53}) = 1.03 \times 10^6 \text{ G}$$

with an uncertainty of about 1%.

A beam of unenriched iron atoms was next produced in an effort to study the hfs of the free Fe^{57} atom. Many resonances have been observed at several values of the magnetic field. The observed resonances are only about 1/300 as intense as the Fe^{56} ground-state resonance. Although this is just the intensity expected for the Fe^{57} transitions, the frequencies of most of the observed resonances do not fall at the values expected for Fe^{57}. Further investigation has shown that they are probably due to Fe^{56} atoms in metastable atomic states lying 7000 cm^{-1} or more above the ^5D ground state. The factor of 300 checks well with the relative populations of the Fe^{56} states expected from the Boltzmann distribution in the oven.

Since the electronic g factors of these levels are of interest theoretically, precise g factors will be obtained for those states that can readily be seen. It is of interest to note that the unusually great sensitivity of the Mark II detection system permits careful examination of a great number of such metastable states throughout the periodic table.

At least one of the resonances observed in iron does not appear to be Fe^{56*}; instead it occurs at the frequency expected for Fe^{57}. It is therefore believed that we are observing Fe^{57} and efforts are being made to measure the hfs of Fe^{57}.

Since the last report, a paper entitled "Nuclear Spin and Magnetic Hyperfine Interaction of 12-Day Ge^{71}," by W. J. Childs and L. S. Goodman, has been accepted for publication in the Physical Review.

I-98-31 Unbound Nuclear Levels in the KeV Region (51210-01)

Carl T. Hibdon

METHODS OF MEASUREMENT

In the studies of unbound nuclear levels in the keV region of neutron energies, many small peaks have been observed. Recently, some of these peaks have been restudied. The schematic arrangement of the neutron counters is shown in Fig. 7. For both flat- and self-detection measurements, neutron counter No. 1 was used in its usual position[1] to count neutrons emitted at an angle of 120° with respect to the direction of the proton beam. The data are normalized to the counts recorded by counter No. 3, which also counts neutrons emitted at an angle of 120° with respect to the direction of the proton beam. To obtain a third type of data, counter No. 2 is used in conjunction with No. 1. The result obtained by this means is a ratio[2] of the neutrons scattered by detector sample B and registered by counter No. 1 to the neutrons scattered by detector sample C and registered by counter No.

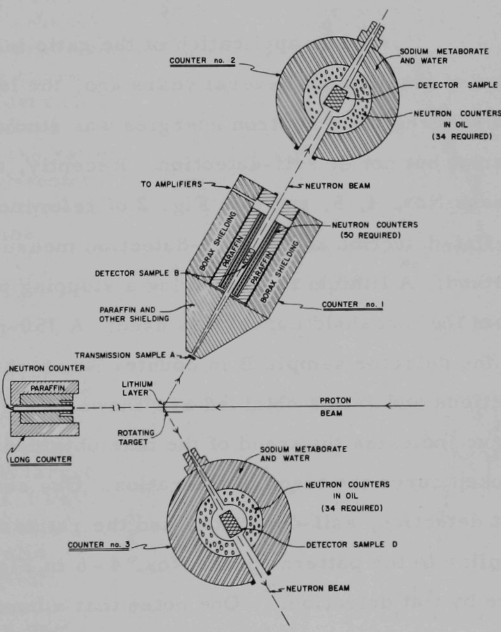

Fig. 7. Schematic arrangement of the neutron counters, lithium target, and long counter as used for measurements at 120° with respect to the direction of the proton beam.

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[1] C. T. Hibdon, Nucl. Instr. and Methods 17, 177 (1962), Fig. 1.

[2] The ratio method was suggested by A. S. Langsdorf, Jr.

2. This ratio is computed only when the transmission sample A is out of the beam and a self-detection detector sample is used for sample B. The ratio is expected to vary as the cross section varies and to show peaks where they occur in the cross section. The advantage of this ratio is that it is self monitoring with respect to changes in intensity. The background of counter No. 1 is obtained by removing detector sample B. The background of counter No. 2 can be obtained by replacing detector sample B by a block of lucite or graphite 6 in. long. Samples C and D are blocks of graphite 6 in. long.

ALUMINUM

The application of the ratio method is well illustrated in the case of aluminum. Several years ago, the level structure of aluminum in the keV region of neutron energies was studied by flat-detection measurements[3] but not by self-detection. Recently, the region from 85 to 95 keV (peaks Nos. 4, 5, and 6 in Fig. 2 of reference 2) has been reinvestigated by flat-detection and by self-detection measurements and also by the ratio method. A lithium target having a stopping power of 0.75 keV (determined from the threshold curve) was used. A 750-mil aluminum sample served as the detector sample B in counter No. 1 shown in Fig. 7. The cross sections and ratios obtained are shown in Fig. 8, in which the unbroken curve indicates the trend of the data obtained by flat detection and the broken curve the trend of the ratios. One sees that the data obtained by flat detection, self-detection, and the ratios all show a pattern of peaks similar to the pattern (peaks Nos. 4 - 6 in Fig. 2 of Ref. 2) obtained before by flat detection.[3] One notes that a hump occurs in all the data on the high-energy side of the group of resonances. This appears to be sufficiently pronounced to indicate the presence of a peak near 90 keV. The change in the peaks when the thickness of the lithium target was increased

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[3] C. T. Hibdon, Phys. Rev. 114, 179 (1959).

from 0.75 to 1.10 keV is shown by the data in Fig. 9. These data, which cover the region from 70 to 94 keV, were obtained with a lithium target having a stopping power of 1.1 keV (determined from the threshold curve).

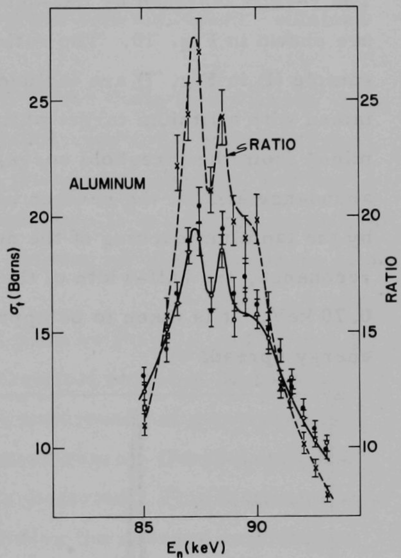

Fig. 8. Neutron cross sections and ratios of aluminum. These data for neutron energies from 85 to 93 keV were obtained with a lithium target having a stopping power of 0.75 keV. Open circles show data obtained by flat detection, solid circles data by self-detection. Data shown by crosses are the ratios obtained as described in the text. The unbroken curve indicates the trend of the data obtained by flat detection and the broken curve the trend of the ratios. A 750-mil self-detection detector sample was used to obtain the self-detection data and the ratios.

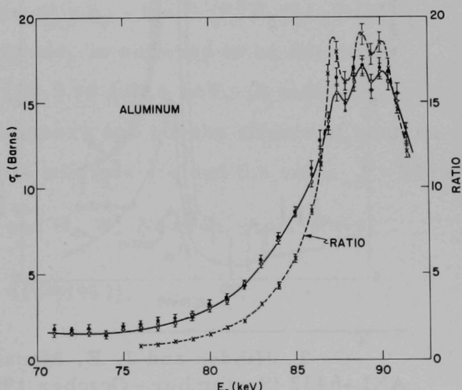

Fig. 9. Neutron cross sections and ratios of aluminum in the region from 72 to 92 keV. These data were obtained by a lithium target with a stopping power of 1.1 keV. Open circles indicate data obtained by flat detection; solid circles data by self-detection. Data shown by crosses are the ratios obtained by use of a 750-mil aluminum detector sample. The unbroken curve indicates the trend of the flat-detection data and the broken curve the trend of the ratios.

THE 131-KEV RESONANCE OF Fe^{56}

In order to obtain an estimate of the neutron energy spread, the very narrow 131-keV s-wave resonance of Fe^{56} was studied in detail. The results obtained by flat-detection and self-detection measurements are shown in Fig. 10. The ratios obtained by a 500- and a 250-mil detector sample (B in Fig. 7) are included also in Fig. 10. These data were obtained with a lithium target which had a stopping power of 0.95 keV (determined from the threshold curve) and have been corrected for the isotopic abundance and for the neutron background due to the scattering of neutrons by the tantalum backing of the neutron target.[1] The observed width of this resonance, the half-width of the peak in the flat-detection data, is about 0.70 keV. It is taken to be approximately the effective over-all neutron energy spread.

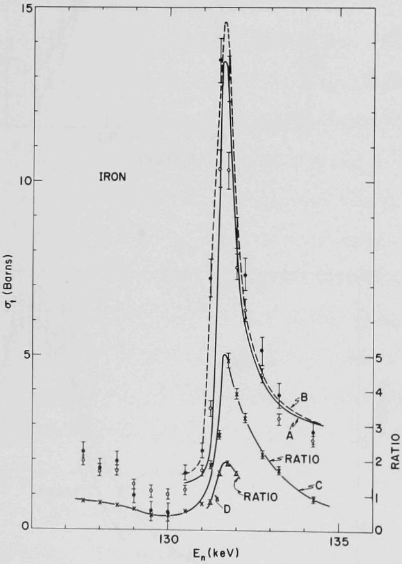

Fig. 10. Neutron cross sections and ratios of iron from 127.5 to 134.5 keV. These data were obtained with a lithium target of 0.95-keV stopping power. Open circles indicate data obtained by flat detection, solid circles data by self-detection. Crosses show ratios obtained with a 500-mil iron detector sample and triangles the ratios obtained with a 250-mil sample. Curves C and D show the trends of the ratios. The parameters and neutron energy spread obtained by the method of analysis given by Monahan and Hibdon[4] were used to compute the cross section over the region of the resonance. The results for flat detection are shown by curve A and for self-detection by curve B.

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[4] C. T. Hibdon and J. E. Monahan, Physics Division Summary Report ANL-6432 (September - October 1961), p. 4.

The resonance has also been analyzed by the method developed by Monahan and Hibdon.[4] This analysis yields a width $\Gamma = 375 \pm 10$ eV, a resonance energy $E_r = 131.5$ keV, and a neutron energy spread $\Delta E_n = 0.65 \pm 0.20$ keV. This value of the width is to be compared with the value $\Gamma = 400$ eV which other experimenters[5] obtained by an area analysis.

A value of ΔE_n of about 0.70 keV disagrees with the value of 1.6 keV expected when the aperture of the collimator of the neutron counter subtends an angle of about 1° at the neutron source. Further work is needed to find out whether the reduction in the energy spread results from a slight misalignment of the counting equipment or from some other cause.

This analysis also gave a peak height $\sigma_{max} = 17.6 \pm 1.6$ barns, compared with a single-level theoretical height of 20.5 barns. The analysis is beset by the fact that the occurrence of many s-wave levels in Fe^{56} leads to strong mutual interference. Consequently the shape of the 131-keV resonance is highly distorted. This distortion was taken into account approximately by including the average contribution of the resonances in the hard-sphere phase shift. The average value of the R function was calculated from the known widths and energies of these levels and the "corrected" phase angle $\phi_0' = \phi_0 - \tan^{-1} [R^0 P_0 / (1 - R^0 s)]$. This correction, although somewhat crude, is believed to be adequate over the small energy interval from 130.5 to 134.5 keV. A multiple-level analysis[6] was attempted several years ago but the effects of neutron energy spread were not included. This analysis yielded the value $\Gamma = 500$ eV.

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[5] C. D. Bowman, E. G. Bilpuch, and H. W. Newson, Ann. Phys. (New York) 17, 319 (1962).

[6] C. T. Hibdon, Phys. Rev. 108, 414 (1957).

I-131-1 A Variety of Perceptron for Recognition of Nuclear Events

(51210-01)

J. A. Gregory (AMD) and G. R. Ringo

I. INTRODUCTION

The mechanization of the procedure for identifying interesting events is a problem of increasing importance in nuclear and particle physics. It is particularly critical in work with emulsions, for example, in which it is desirable to scan large volumes of material with microscopes which may show 10^{-8} cc or less in a single view. The problem is not new, of course, and has been attacked in many different ways. Indeed even a simple counter array with coincidence-anticoincidence requirements can be considered as a pattern discriminator and a great deal of ingenuity has been and is being devoted to devising efficient special-purpose selection schemes. It seems reasonable to predict that in the near future, at least, specific schemes rationally designed to select wanted events will be the efficient and practical way to do this. However, as the events being selected grow more complex and the cost of large-scale data processing continues to drop, the possibility of devising a general-purpose machine for recognition of different classes of nuclear events and similar phenomena becomes more attractive.

Several schemes have been suggested to do general pattern recognition. With no pretense at completeness, we would like to mention here the work of Farley and Clark,[1] Rosenblatt and his group,[2-4]

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[1] W. A. Clark and B. G. Farley, I.R.E., Trans. Professional Group on Information Theory 4, 76 (1954).

[2] F. Rosenblatt, Principles of Neurodynamics: Perceptrons and the Theory of Brain Mechanisms (Spartan Books, Washington, D.C., 1961).

[3] H. D. Block, Revs. Modern Phys. 34, 123 (1962).

[4] H. D. Block, B. W. Knight, Jr., and F. Rosenblatt, Revs. Modern Phys. 134, 135 (1962).

Uhr and Vossler,[5] Bormer,[6] and Gamba and his group.[7] (The literature in this field is widely scattered.[8] It is almost a tradition to describe each new scheme in a different journal.) Since the scheme to be described here is rather closely related to the Perceptron of F. Rosenblatt, we will first give a brief description of a simplified type of Perceptron. One of these is roughly sketched in Fig.11. Random connections are made from sensory units to associator units and from associator units to response units. Signals flow only in the directions shown. The sensory units might be, for example, a square array of photocells focused on a picture or a linear array of filters giving the frequency spectra of an acoustic signal, etc. The sensory units put out a binary signal; if an associator unit receives enough signals from the sensory units to exceed some threshold, it "fires" (puts out a signal to the response units to which it is connected). The response units behave in a corresponding fashion.

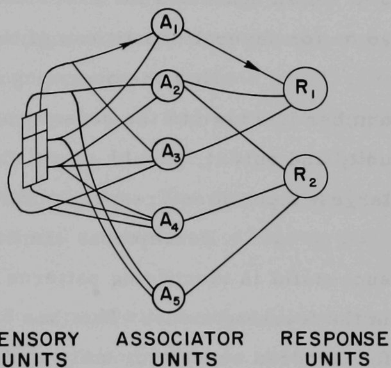

Fig. 11. A rough sketch of a simple Perceptron.

The device has two modes: a learning mode and an operating mode. Assume for concreteness that it is to be taught to

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[5] L. Uhr and C. Vossler, Proceedings of the Western Joint Computer Conference, 1961, p. 550.

[6] R. E. Bormer, IBM Jour. Res. and Dev. 6, 353 (1962).

[7] A. Gamba, G. Palmieri, and R. Sanna, Nuovo Cimento Suppl. 23, 280 (1962).

[8] For a good bibliography see Section 5 of "Current Research and Development in Scientific Documentation," No. 11, November, 1962, NSF-63-5, National Science Foundation.

distinguish the printed numbers 0, 1, 2. One response unit would be selected in advance and at random as the 0 unit, R_0; another as the 1 unit, R_1; etc. In the learning mode, a 0 is shown to the sensory units and all associator units that send signals to R_0 have their signals strengthened and all that sent signals to other response units are weakened. (Other ways of modifying the network, such as raising the threshold for unfavorable associator units, etc., are possible, of course, and several have been found to give interesting results.) Then a 1 is shown to the sensory units and corresponding changes are made. After the other numbers have been treated in the same fashion, 0 is shown again and the associators adjusted. Then 1 is shown, and so on for several repetitions of the set of numbers.

Now the operating mode can be tried. In this mode a number is shown to the sensory units; and the corresponding response unit, and only it, should give a signal (or at least it should have the largest input of any response unit).

Perceptrons similar to the one described have been quite successful in identifying patterns that are identical to the patterns used in the learning mode. This has been done with machines having only a few hundred associator units at most and with patterns of quite varied character — even with some noise added. There is, however, great interest in the further and obviously more difficult stage of recognizing patterns that are not identical to any patterns used in learning but belong to the same class in some sense discernible to an observer. While the Perceptron has had some success on this "generalization" problem, it has not solved it.

II. DESCRIPTION OF METHOD

The present study was undertaken in the hope of contributing to the solution of this last problem. The proposed pattern-recognition device, which was simulated on a general-purpose computer, would be very similar to the one shown in Fig. 11. However, in the learning mode, representative patterns of the class to be recognized would be shown to the sensory units, then representative patterns of the class to be discriminated against would follow. Response units would not be picked in advance; rather their responses to these two classes would be examined. Those response units that fired frequently for the first class and infrequently for the second class would be saved. Call them R_W units. Those that did the reverse would also be saved. Call them R_U units. In the operating mode a test pattern would be classified on the basis of whether a larger fraction of the R_W or R_U units fired.

The Perceptron is based on current theories of the operation of the brain; in effect it takes a complicated random network and modifies it to force it to give a desired response at certain preselected points. The thought behind the present variant is that perhaps the brain recognizes a pattern by finding certain points in a very large random network at which discrimination already occurs. The network leading up to these points would then be frozen and connections to higher association centers would be established.

Thus in the brain a few neurons out of the millions available at some appropriate layer at any given time would be selected. In the recognition method studied here, this is simulated by trying many response units serially. However, it should probably be said explicitly that in this work the interest is almost exclusively in finding a useful method of pattern recognition. No serious connection with neurophysiology is intended or claimed.

The device simulated in this work had 80 sensory units in an 8×10 array. Each of these had a 50% chance to be connected to excitory or inhibitory inputs of each of 400 associator units. (Connection to both excitory and inhibitory inputs was equivalent to no connection to either.) If the sum of the excitory inputs exceeded the inhibitory, the associator unit produced an output of unit strength. The outputs of the associator units in turn were connected randomly to the excitory and inhibitory inputs of the response units which responded as did the associator units. In the computer program the excitory signal to an associator unit, for example, was found by counting the number of 1's in the logical product of the 80-bit word representing the pattern under study and a random 80-bit word representing the excitory connections of the associator unit. This was compared with the number of 1's in the logical product of the same 80-bit word representing the pattern and a different random 80-bit word representing the inhibitory connections of the associator unit. If the number of 1's in the first product was greater than in the second, the associator unit was considered to send a signal to the next level — otherwise not. Fig. 12 gives a rough indication of a small portion of the equivalent network.

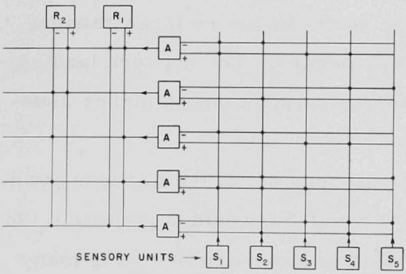

Fig. 12. A greatly simplified diagram of the network simulated in this study. The + and - signs refer to the excitory and inhibitory inputs, respectively.

III. RESULTS

As a test problem selected to be of obvious interest in identification of nuclear events, Y's were to be distinguished from X's and straight lines. A few samples of the patterns used in the learning and test (operating) modes are shown in Fig. 13. As can be seen, the 8 × 10 array is so coarse that the patterns have deteriorated in quality considerably. This process was aggravated by the addition of some straight lines and noise as background in the Y patterns as well as in the X and straight-line patterns. The patterns were categorized on the basis of what they

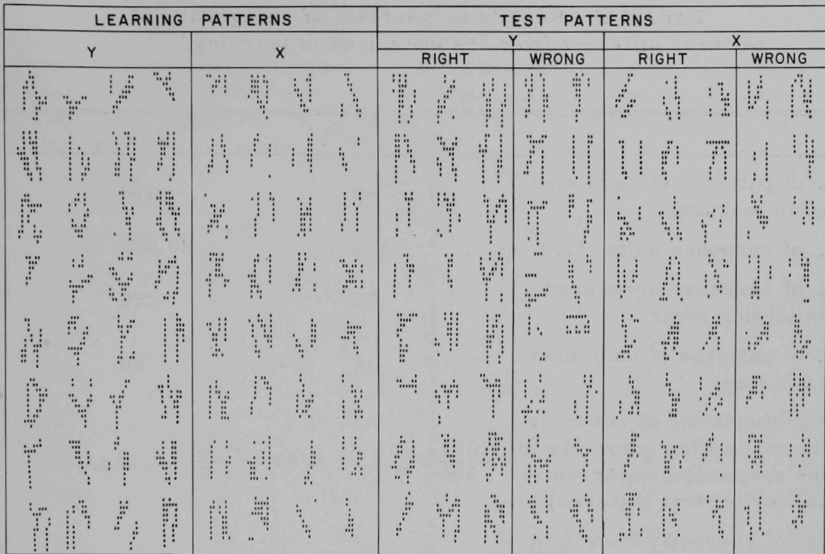

Fig. 13. Representative patterns of the categories indicated. These 144 patterns are digitized on an 8×10-unit mosaic from hand printed X's and Y's of random position, size, orientation ($\pm 30^{\circ}$) and opening angle (30° — 120°). The X patterns include some that had no X's, only straight lines.

were in the original hand-drawn figures. "Right" means, of course, test patterns that were correctly identified by the program in the operating mode and "wrong" designates patterns incorrectly identified. Two sets were run with the parameters and results shown in Table II. (The categories of Fig. 13 apply to the second, larger test.) When an independent observer (unfamiliar with the selections made by the program) categorized the test patterns and discarded the ambiguous ones on the basis of their digitized appearance as in Fig. 13, the ratio of correct to incorrect choices by the program rose to 2.4 ± 0.4.

The results of a typical run in the learning mode of the larger test are shown in Table III. In this test a response unit was selected if

TABLE II. Results of two tests of recognition of patterns different from the ones used in learning.

	Test 1	Test 2
No. of patterns of each kind used in learning	50	100
No. of response units tried	3500	20 000
No. of response units used in operating mode	70	220
No. of patterns of each kind used in test	45	80
Ratio of number of response units responding correctly to those responding incorrectly (total for all test patterns)	$\frac{1001}{906} = 1.11 \pm 0.05$	$\frac{6966}{6210} = 1.13 \pm 0.02$
Ratio of correctly identified test patterns to wrongly identified ones	1.3 ± 0.3	1.8 ± 0.3

TABLE III. Results of a typical learning run con- consisting of 100 patterns. The score is the number of patterns that caused the response unit to fire.

Response unit	Score for Y patterns	Score for X patterns	Response unit	Score for Y patterns	Score for X patterns
1	20	26	9	6	6
2	54	56	10	94	92
3	5	4	11	71	77
4	6	13	12	19	22
5	42	63	13	1	5
6	36	39	14	97	91
7	44	43	15	4	4
8	72	76	16	98	88

TABLE III (cont'd)

Response unit	Score for Y patterns	Score for X patterns	Response unit	Score for Y patterns	Score for X patterns
17	92	92	34	68	66
18	8	17	35	85	80
19	10	10	36	72	75
20	90	84	37	92	89
21	70	56	38	30	40
22	67	61	39	99	96
23	22	25	40	14	15
24	50	41	41	26	26
25	5	11	42	10	25
26	52	65	43	42	50
27	37	40	44	100	95
28	88	77	45	93	74
29	15	12	46*	42	20
30	53	61	47	53	54
31	35	30	48	9	16
32	13	15	49	59	48
33	62	59	50	70	70

*Selected as an R_Y unit.

$$\frac{|N_X - N_Y|^{3/2}}{\sqrt{N_X} + \sqrt{N_Y}} \geq 7,$$

where N_X is the number of X patterns causing the unit to fire and N_Y is the number of Y patterns doing the same. This criterion depends mainly on the statistical significance of the difference between N_X and N_Y; the $\frac{3}{2}$ power gives some bias in favor of larger numbers as such, on the grounds that of two units of equal reliability the one responding to the larger percentage of the patterns is apt to be more useful. As can be seen in Table II, this criterion selected about one response unit out of 100 random ones generated by the program.

Each pattern used in the test mode differed from every pattern used in the learning mode by at least 10 bits of the 80 which constituted the pattern as seen by the computer.

While the results are clearly of statistical significance, they are hardly at a useful level of reliability. However, it is interesting to note that the recognition method itself succeeded in discriminating the two classes of test patterns approximately as well as human observers when the later worked with the patterns as shown in Fig. 13 and the additional information that one set was supposed to be Y's. It seems quite likely that the reliability would have been considerably higher if the learning as well as the test patterns had been hand picked for clarity after being digitized.

IV. IMPROVEMENTS

1. Higher Resolution in the Patterns

An obvious but somewhat expensive improvement in this recognition technique would be to use a larger sensory array — at least 16 × 20 lines in area. This would not seriously increase the time of the learning program but it would directly affect the size and cost of any device built to use this recognition technique. It seems worthwhile, therefore, to consider other possibilities for improving reliability.

2. Greater Speed

Since this program required roughly 10 sec to test a pattern, a radical improvement in speed is obviously needed. Fortunately, this would be relatively easy to do with available components. A full-sized version of the network of Fig. 12, built with analog summation circuits, would have a response time of about 10^{-8} sec. A device suitable for use in the learning mode would require more complicated ways of making the random connections to the response units (and recording the useful ones) but a similar time scale for the response to an individual pattern does not seem unreasonable. The simple use of the radically greater speed to select response units from a much larger field would almost certainly produce great improvements in reliability.

3. Variation of Associator Units

It seems quite reasonable that some associator units will be much more efficient than others in producing useful networks for a given class of patterns. In fact the PAPPA machine No. 2 built by Gamba and his co-workers[7] was in its essentials equivalent to the present scheme; the learning process described earlier was applied to the associator units and the selected associator units were connected together to one response unit. It was a fairly successful device and suggests the value of selecting associator units. With a radically faster method, as mentioned above, it would be practical to test say 100 000 sets of associator units, testing 10 000 response units in each and finally selecting the set of associator units that led to the most useful response units. It is even plausible that a set of associator units so selected will have more than average usefulness for different classes of patterns similar to classes which were used in selecting that set. For example, if handwritten A's, B's, and C's are used in selecting the set of associator units, this set may well be useful on the rest of the alphabet.

There is, of course, no reason that all connections in this method have to be made in a random fashion. It would be quite possible and perhaps useful to construct associator units on a rational basis determined by the general character of the patterns that are of interest. These associator units in turn might be combined with random associator units; but in any case the response units would be chosen by selecting randomly constructed units.

4. More Efficient Trials

The learning process might be more efficient if the patterns were selected to cover the different types of variation in a systematic manner. Also, J. W. Butler has suggested that instead of random variation of all of the connections of the response units, random variation of a few percent of the connections at a time, starting with response units that had given a good performance, might lead to considerably better ones in an efficient manner.

The class of patterns covered in this test was very broad; perhaps unnecessarily so. In particular, the small Y's and X's, which gave considerable difficulty because of the coarse digitizing, might well be omitted for some purposes.

5. More Layers

The outputs of the response units could certainly be connected in a random way to another layer of units and these in turn to still another layer, etc. This would presumably be the way to handle more complicated patterns; but if several layers are needed to recognize even simple patterns of the type used in this test, it is hard to see how to start to organize these.

6. Weighting

It would be interesting to try units whose output varied with the algebraic sum of excitory and inhibitory inputs. This would presumably differ from the biological models but in the present state of our knowledge, these models should be considered more as suggestions than limits.

7. Density of Connections

The density of connections (solid dots in Fig. 13) used in this test was about $\frac{1}{4}$. This comes about even though there was a 50% chance that any given connection was made because an excitory and inhibitory connection to the same line cancel out. This density seems somewhat too high in retrospect; considerably lower densities should be tried.

8. Size of Array

Roughly speaking, a decrease in the size of the array of associator units could be traded for an increase in the number of response units tried in the learning mode. There is no guarantee that the particular balance chosen is optimum; considerably different ones should be tried.

9. Scanning

The discrimination would probably be more reliable if a pattern being tested were scanned (that is, presented to the sensory units in about 10 positions slightly displaced from each other) and a decision were made on the basis of the average result. This assumes, of course, that the speed in the testing mode is rather high.

of connections; these models should be considered these as [illegible] tions with limits.

C. Density of Connections

The density of connections (solid dots in Fig. 17) used in this test was about [illegible]. This comes about even though there was a 50% chance that any given connection was made because excitatory and inhibitory connections to the same line cancel out. This density seems about what [illegible] in retrospect considerably lower densities should be used.

D. Size of Array

Roughly speaking, a decrease in the size of the [illegible] could be traded for an increase in the number of [illegible] in the learning [illegible]. There is [illegible] estimates that the [illegible] chosen is optimum [illegible] considerably different [illegible] should be tried.

[illegible]

The discrimination [illegible] reasonably [illegible] reliable if [illegible] patterns [illegible] tested were [illegible] the accuracy [illegible] in about 10 positions [illegible] and [illegible] decisions were made on the basis [illegible] this assumes [illegible] that the speed [illegible]

V. THEORETICAL PHYSICS, GENERAL

V-2-19 Properties of Light Nuclei (51210-01)

Dieter Kurath

GROUND STATE OF B^{11}

The properties of B^{11} have been investigated previously[1] by use of an intermediate-coupling shell model. A recently detected error in the energy matrix of the ($I = \frac{3}{2}$, $T = \frac{1}{2}$) states changes the earlier results. While the spectrum of energy levels is not seriously affected, the wave function of the ground state is changed in a way that results in a large alteration of the calculated magnetic moment. An example of this change is that when the intermediate-coupling parameter has the value $a/K = 4.5$, the magnetic moment calculated with the new wave function is $\mu = +2.15$ nm, whereas the old wave function gave $\mu = +2.85$ nm. The experimental value is $\mu = +2.69$ nm.

An alternative way to obtain wave functions for low-lying states in the 1p shell is to generate them[2] from Nilsson wave functions. For B^{11} there are two generators that produce ($I = \frac{3}{2}$, $T = \frac{1}{2}$) states. These generators differ in that the projection of angular momentum on the nuclear symmetry axis is $K = \frac{3}{2}$ for one, $K = \frac{1}{2}$ for the other. The wave functions were projected for a value of the Nilsson parameter $\eta = -8$, appropriate[2] to the intermediate-coupling parameter $a/K = 4.5$. Then a linear combination of the $K = \frac{1}{2}$ and the $K = \frac{3}{2}$ wave functions was formed subject to the requirement that it gave the experimental value for the magnetic moment.

Three points of interest arise from investigation with the resulting wave function:

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[1] D. Kurath, Phys. Rev. 101, 216 (1956); 106, 975 (1957).

[2] D. Kurath, and L. Pičman, Nucl. Phys. 10, 313 (1959).

(1) The linear combination determined in this way is very close to the result of a Coriolis coupling calculation with the two generated states as described in Ref. 2.

(2) The wave function has an overlap of 0.967 with the wave function obtained by diagonalization. The latter wave function gave a magnetic moment μ = 2.15 nm.

(3) The magnetic moment computed for the mirror nucleus $C^{11}$is μ = -0.94 nm, in good agreement with the preliminary experimental value.[3]

The sensitivity of the calculated magnetic moment to relatively small changes in the wave function is quite surprising. An exploratory intermediate-coupling calculation will be done to see if one can vary the two-body interaction to obtain an energy spectrum and magnetic moment for B^{11} which are in better agreement with experiment than previous results. It will also be of interest in connection with electron-scattering experiments to calculate M1 transition strengths B_{M1} from the ground state to various excited states. Here calculations with the old wave functions indicate a concentration of such strength in low-lying levels, a feature which should carry over to the new calculation.

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[3] R. A. Haberstroh, W. J. Kossler, O. Ames, and D. R. Hamilton, Bull. Am. Phys. Soc. 8, 8 (1962), and private communication.

V-15-13 Statistical Properties of Nuclear Energy States (51210-01)

N. Rosenzweig

ANOMALOUS STATISTICS OF PARTIAL RADIATION WIDTHS

This note indicates how the existing statistical model[1,2] may be extended in order to describe such anomalies as the unexpectedly small fluctuations in partial radiation widths which have been reported

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[1] C. E. Porter and R. G. Thomas, Phys. Rev. 104, 483 (1956).

[2] T. J. Krieger and C. E. Porter (to be published).

for U^{239}.[3-8]

In order to bring the discrepancy between experiment and theory into sharp focus, we begin by describing the essential content of the theory. Let the set of initial compound states be denoted by $\psi_1, \cdots, \psi_N$ and the final states, after the emission of a single gamma ray, by $\phi_1, \cdots, \phi_n$. The reduced partial widths are of the form

$$\Gamma_{ij} = (\psi_i, V\phi_j)^2 . \tag{1}$$

The essence of the statistical model is the introduction of an appropriate distribution of compound states, which is best done in a pertinent representation of states: Let P denote the projection onto the space spanned by the N compound states. Let the space spanned by $PV\phi_i (i = 1, \cdots, n)$ be denoted by Σ_n. Let us assume that Σ_n is n dimensional, and let $u_1, u_2, \cdots, u_n$ be an orthonormal basis in Σ_n. Let this basis be extended so that

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[3] D. J. Hughes, Brookhaven National Laboratory Report BNL-4464 (1959).

[4] D. J. Hughes, H. Palevsky, H. H. Bolotin, and R. E. Chrien in <u>Proceedings of the International Conference on Nuclear Structure, Kingston, Canada, 1960</u>, edited by D. A. Bromley and E. W. Vogt (University of Toronto Press, Toronto), p. 771.

[5] C. Corge, V. D. Huynh, J. Julien, J. Morgenstern, and F. Netter, J. phys. radium <u>22</u>, 722 (1961).

[6] H. E. Jackson and L. M. Bollinger, Bull. Am. Phys. Soc. <u>6</u>, 274 (1961). These writers find that the fluctuations are greater than reported in Ref. 3, 4, and 5.

[7] L. M. Bollinger, R. E. Coté, R. T. Carpenter, and J. P. Marion, Phys. Rev. (in press). These workers find that the standard theory is <u>not</u> contradicted by the evidence for seven nuclides (excluding U^{239}) and their reservations regarding the U^{239} data should also be noted.

[8] N. F. Fiebiger, Bull. Am. Phys. Soc. <u>7</u>, 11 (1962).

$$\psi_i = \sum_{j=1}^{N} x_{ij}\, u_j . \tag{2}$$

All the results of the theory may be obtained from the assumption that the distribution of the orthogonal matrix $\|x_{ij}\|$ is given by the invariant measure on the group of orthogonal matrices in N dimensions. This distribution may also be regarded as the consequence of a principle of uniformity which states that the distribution of compound states shall be invariant under an arbitrary change in the form of the residual interaction between the nucleons.[9,10]

It follows from the above that any one of the compound states is distributed uniformly on the surface of the unit sphere in N dimensions, i.e., with the probability density[11]

$$P(x_1, x_2 \cdots x_N) \propto \delta\left[\sum_{i=1}^{N} x_i^2 - 1\right], \quad N \to \infty . \tag{3}$$

The statistics of the n partial widths depend only on the distribution of the first n components, which, since N is assumed to be very large, is given asymptotically by

$$P(x_1, x_2, \cdots x_n) \propto \exp\left(-\frac{N}{2}\sum_{i=1}^{N} x_i^2\right) . \tag{4}$$

From this simple distribution all the standard results may be obtained without further assumptions. In particular, the distribution of a single partial width is given by the Porter-Thomas distribution[1]

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[9] F. J. Dyson, J. Math. Phys. 3, 140 (1962).

[10] N. Rosenzweig, Bull. Am. Phys. Soc. 7, 91 (1962) and Brandeis University Lectures, 1962 (W. A. Benjamin, Inc., New York, 1963).

[11] The first index of x_{ij} has been dropped, since the distribution (10) is the same for each compound state.

$$P(y) = \frac{1}{\sqrt{2\pi}} \frac{e^{-y/2}}{\sqrt{y}}, \qquad y = \frac{\Gamma}{\langle\Gamma\rangle} \tag{5}$$

which has a relative variance

$$\kappa^2 \equiv \frac{\langle\Gamma^2\rangle - \langle\Gamma\rangle^2}{\langle\Gamma\rangle^2} = 2. \tag{6}$$

The correlation coefficient τ_{ij} between two partial widths has the transparent form

$$\tau_{ij} = \frac{(PV\phi_i, PV\phi_j)^2}{|PV\phi_i|^2 \, |PV\phi_j|^2} \tag{7}$$

and is non-negative as noted by Krieger and Porter.[2]

Let us now consider the sum of several partial widths between the same initial state and the n final states. This sum

$$S = \Gamma_1 + \Gamma_2 + \cdot \cdot \cdot + \Gamma_n, \tag{8}$$

is the quantity measured in some experiments.[3-7] If the relative variance of each partial width is 2 and the correlation coefficients are positive — as is the case in the above theory — then it follows rigorously that

$$n \geqslant \frac{2}{\Delta^2}, \tag{9a}$$

where

$$\Delta^2 = \frac{\langle S^2\rangle - \langle S\rangle^2}{\langle S\rangle^2} \tag{9b}$$

is the relative variance of the sum of partial widths. This relative variance may be estimated experimentally by averaging over a sufficient number of compound states. If the theory is assumed to be applicable to U^{239}, then the experimental evidence implies that $n \geqslant 20$. Actually, however, n is thought to be of the order 5.[8] Therefore, the assumption that the experimental evidence is reliable forces one to the conclusion that the above theory fails in this particular case.

A discrepancy of the kind illustrated above indicates that the subspace Σ_n has special properties which must find expression in the statistical theory.[12] One fairly natural way of formulating this idea consists in allowing only those changes in residual interactions which induce orthogonal transformations (of the N compound states) under which Σ_n is an invariant subspace. The principle of uniformity that is appropriate under this assumption states: <u>The joint distribution of the N orthogonal compound states shall be invariant under all orthogonal transformations in N dimensions under which Σ_n is invariant.</u> We shall not describe here the entire distribution which results from this requirement, but only the part which is relevant for the solution of our problem, namely, the joint distribution of the first n components. It is given by

$$P(x_1, x_2, \cdot \cdot \cdot, x_n) \propto \int_0^1 w(r)\, \delta \left[\sum_{i=1}^{n} x_i^2 - r^2\right] r\, dr. \qquad (10)$$

Thus, P consists of a superposition of spherical shells weighted according to a density function w(r). The form of the weighting function cannot be inferred from general principles, but must be chosen on the basis of physical insight into the particular case or in such a way as to bring agreement between theory and experiment. In view of the fact that our knowledge of U^{239} is not sufficient for a determination of w(r), we will record some pertinent results which are not immediately affected by this limitation. For example, the relative variance of a single partial width, κ^2, is restricted (only) by the inequality

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[12] Deviations from the extreme statistical model have been formulated in other instances, for example, when a complex system has approximate constants of the motion; see N. Rosenzweig and C. E. Porter, Phys. Rev. 120, 1698 (1960), Sec. V, 2; and F. J. Dyson, J. Math. Phys. 3, 1191 (1962).

$$\kappa^2 \geqslant \frac{2(n-1)}{n+2} . \tag{11}$$

The coefficient of correlation ρ_{ij} between two partial widths may be expressed in terms of κ^2 as follows:

$$\rho_{ij} = 1 - \frac{2}{3}(1-\tau_{ij})\left(\frac{1+\kappa^2}{\kappa^2}\right) , \tag{12}$$

where τ_{ij} is defined by Eq. (7). It will be noted that the correlation coefficient in our theory may be either positive or negative.[13]

Let us now return to a discussion of the experimentally observed value of Δ^2, the relative variance of the sum of several partial widths! A little reflection shows that the small value of Δ^2, which has been reported, can be described with many sets of values of the parameters κ^2, $\langle\Gamma_i\rangle$, and τ_{ij}. However, our model, in conjunction with the measured value of Δ^2, does place some limitations on the values of the parameters. First, we will show that the assumption

$$\sum_{i<j} \langle\Gamma_i\rangle\langle\Gamma_j\rangle\, \rho_{ij} \geqslant 0 \tag{13}$$

is untenable. If (13) were true, then

$$n \geqslant \frac{\kappa^2}{\Delta^2} \geqslant \frac{2(n-1)}{\Delta^2(n+2)} . \tag{14}$$

For any reasonable value of n, say $2 \leqslant n \leqslant 10$, a substitution of the observed value of Δ^2 in (14) leads to a contradiction. Hence, at least one of the correlation coefficients in (13) must be negative. From this we may conclude, in the light of (12), that

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[13] P. A. Moldauer has suggested that a negative correlation between reaction widths may be required for an understanding of some reaction cross sections. [Proceedings of the Symposium on Statistical Properties of Atomic and Nuclear Spectra, State University of New York at Stony Brook (1963)].

$$\kappa^2 \leqslant \frac{2(1-\tau)}{(1+2\tau)} , \tag{15}$$

where τ is the largest of the set of positive numbers τ_{ij}. We are now ready to state our main conclusion: The analysis of the observed value of Δ^2 in terms of our model implies that at least one of the correlation coefficients ρ_{ij} must be negative and that the relative variance of a single partial width κ^2 must be smaller than 2.

It would be extremely interesting to know whether or not κ^2 for U^{239} has a velue which is substantially smaller than 2. However, a small value of κ^2 does not necessarily imply that the shape of the distribution of a single partial width will be qualitatively different from the Porter-Thomas distribution. In order to prove this assertion, let us consider the density function

$$w(r) \propto \delta(r^2 - r_0^2) \tag{16}$$

for which κ^2 attains its lower limit:

$$\kappa^2 = \frac{2(n-1)}{(n+2)} . \tag{17}$$

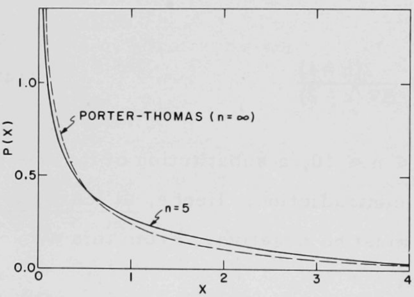

Fig. 14. As an illustration, the distribution of a single partial width of the modified theory based on the density function (6) with n = 5 (solid curve) is compared with the Porter-Thomas distribution (dashed curve).

We have computed the distribution of a single partial width for n = 5 on the above assumption. The result is shown in Fig. 14 for comparison with the Porter-Thomas distribution. Although the two distributions are qualitatively very similar, the relative variance of the modified distribution is only 4/7 of that in the standard theory.

The theory of Porter and Thomas[1] and Krieger and Porter[2] corresponds precisely to the density function

$$w(r) \propto e^{-\frac{N}{2} r^2} , \tag{18}$$

so that our model contains the standard theory as the most important special case.

It needs hardly be emphasized that the above considerations would not have enabled one to predict in advance that U^{239} shall exhibit an anomaly. Similarly, the region of applicability of the standard theory[1,2] is poorly defined. All one can say is that the latter may be expected to apply asymptotically when the system is "sufficiently complex." However, in practice deviations must be expected to occur, and our model is but one example of the kind of departure from the asymptotic theory that will occasionally be observed.

A remark about the connection between the new model and the statistical theory of eigenvalues[14] is in order. It is clear that ensembles of real symmetric matrices exist which have both the Wishart distribution of eigenvalues and the joint distribution of eigenvectors indicated above. Whether or not such an ensemble has a simple form when expressed in terms of the matrix elements of the residual interaction is a question which remains to be investigated.

The writer is especially indebted to the authors of references 2 and 7 for sending him preprints of their articles prior to publication. Helpful discussions with Drs. H. E. Jackson and L. M. Bollinger regarding the U^{239} data and conversations with Drs. J. M. Cook and J. Monahan are gratefully acknowledged.

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[14] E. P. Wigner, Proc. Fourth Canadian Math. Congress, 1957. An extensive bibliography is contained in Reference 9.

V-44-2 Foundations of Quantum Mechanics (51151-01)

H. Ekstein

EXPERIMENTAL VERIFIABILITY OF THE QUANTUM THEORY OF MEASUREMENT

The orthodox theory of measurement in quantum mechanics attributes a primary role to consciousness. Is it possible to design an experiment in which the theory predicts unambiguously an operationally noticeable effect of an act of consciousness upon the course of physical events? The answer found here is Yes for a thought experiment, but No for any realistic experiment. The (unexpected) reason for the negative result is that orthodox quantum mechanics is incomplete in that it fails to define the measurement procedures whose existence it claims.

A full report is in preparation.

PUBLICATIONS SINCE THE LAST REPORT

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Phys. Rev. 131, 774-777 (15 July 1963)

COLLECTIVE EXCITATIONS IN $Ni^{58,60,62}$ AND $Zn^{64,66,68}$
H. W. Broek . . . . (Project I-22)
Phys. Rev. 130, 1914-1925 (1 June 1963)

MÖSSBAUER EFFECT IN CHEMICAL COMPOUNDS OF Xe^{129}
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S. Cohen and W. Swiatecki . . . . (Project V-1)
Ann. Phys. 22, 406-437 (June 1963)

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S. N. Gupta . . . . (Unattached)
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L. L. Lee, Jr., J. P. Schiffer, and D. S. Gemmell . . . . (Project I-27)
Phys. Rev. Letters 10, 496-498 (1 June 1963)

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A. W. Martin and K. C. Wali . . . . (Project V-52)
Phys. Rev. 130, 2455-2467 (15 June 1963)

THE PRINCIPLE OF EQUIVALENCE
F. Rohrlich . . . . (Unattached)
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CALCULATION OF DEUTERON STRIPPING AMPLITUDES USING S-MATRIX REDUCTION TECHNIQUES
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K. Smith and J. L. Uretsky . . . . (Project V-49)
Phys. Rev. 131, 861-867 (15 July 1963)

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S. Wexler and D. C. Hess . . . . (Project II-31)
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(d,p) REACTION ON THE TITANIUM ISOTOPES
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A COMPUTER PROGRAM FOR ANALYSIS OF COMPLEX CONTINUOUS BETA-RAY SPECTRA

S. B. Burson, R. G. Helmer, and T. Gedayloo . . . (Project I-38)
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ANALYSIS OF GAMMA-RAY SPECTRA

J. E. Monahan, S. Raboy, and C. C. Trail . . . . (Project I-55)
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ATOMIC COLLISION SEQUENCES REVEALED IN THE SPUTTERING OF METAL MONOCRYSTALS BY ION BOMBARDMENT IN THE RUTHERFORD COLLISION REGION

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University of California Radiation Laboratory Report UCRL-7332-T (30 April 1963)

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Co-op student report to the University of Detroit (May 16, 1963)

INFORMAL REPORT

THE COMMUTATIVITY OF SUPERSELECTING OPERATORS
H. Ekstein . . . . (Project V-42)
Informal report

ADDITIONAL PAPERS ACCEPTED FOR PUBLICATION

EQUILIBRIUM COMPOSITION OF SULFUR VAPOR
J. Berkowitz and J. R. Marquart . . . .(Project II-29)
J. Chem. Phys. (July 1963)

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L. M. Bollinger, R. E. Coté, R. T. Carpenter, and
J. P. Marion . . . .(Project I-7)
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J. R. Erskine and D. S. Gemmell . . . .(Project I-21)
Nucl. Instr. and Methods (August 1963)

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PROPERTIES OF CAPTURE GAMMA-RAY SPECTRA OF s-WAVE AND p-WAVE RESONANCES IN Zr, Nb, AND Mo
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UNITARY SYMMETRY IN PHOTOPRODUCTION AND OTHER ELECTROMAGNETIC INTERACTIONS
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DISSOCIATION ENERGIES OF SOME METAL SULFIDES
J. R. Marquart and J. Berkowitz . . . .(Project II-28)
J. Chem. Phys. (July 1963)

FLUXOID QUANTIZATION, PAIR SYMMETRY, AND THE GAP ENERGY IN THE CURRENT-CARRYING BCS STATE
M. Peshkin . . . .(Project V-33)
Phys. Rev.

ANOMALOUS STATISTICS OF PARTIAL REACTION WIDTHS
N. Rosenzweig . . . .(Project V-15)
Phys. Letters (15 August 1963)

STATISTICAL MECHANICS OF EQUALLY LIKELY QUANTUM SYSTEMS

N. Rosenzweig . . . .(Project I-15)

Statistical Physics by N. Rosenzweig, G. E. Uhlenbeck, A. F. Siegert, E. Jaynes, and S. Fujita (W. A. Benjamin, Inc., New York)

SEARCH FOR A PARTICLE-STABLE TETRA NEUTRON

J. P. Schiffer and R. Vandenbosch . . . .(Project I-50)

Phys. Letters (15 July 1963)

TECHNIQUES FOR THE STUDY OF RADIATIVE ALPHA-CAPTURE REACTIONS

J. A. Weinman . . . .(Project I-21)

Nucl. Instr. and Methods

PERSONNEL CHANGES IN THE ANL PHYSICS DIVISION

NEW MEMBERS OF THE DIVISION

Staff Members

Dr. Fritz Coester. Born in Berlin, Germany, 1921. Married; four children, Janet, 8; William, 7; Hans, 5; and Michael, 4. Home address: RR # 2, Iowa City, Iowa. Ph.D., University of Zurich, 1943. He has been at Argonne as a Resident Research Associate since 1 August 1962. He became a permanent staff member on 1 June 1963. Theoretical nuclear physics.

Dr. John R. Erskine. Born in Milwaukee, Wisconsin, 1931. Married; five children, David, 6; Therese Ann, 5; Timothy, 3; Mary Clare, $1\frac{1}{2}$; and Paul, infant. Home address: 4804 Highland Avenue, Downers Grove, Illinois. Ph.D., University of Notre Dame, 1960. He has been at Argonne as a Resident Research Associate since 2 July 1962. He became a permanent staff member on 15 May 1963 to work on charged-particle reactions at the Van de Graaff.

Dr. William D. McGlinn. Born in Leavenworth, Kansas, 1930. Married; four sons, William, Jr., 9; Thomas, $6\frac{1}{2}$; Brian, $2\frac{1}{2}$; and Kenneth, 3 weeks old. Home address: 905 Woodland Drive, Wheeling, Illinois. Ph.D., University of Kansas, 1959. He joined the Physics Division on 1 July 1963 to carry on theoretical studies in particle physics.

Resident Research Associates

Mr. Teymoor Gedayloo, Department of Physics, Lawrence College. Beta-ray spectroscopy and supervisor of ACM students. Returned to Argonne on 1 July 1963. (Host: S. B. Burson.)

Dr. Kiyomi Itabashi, Research Associate, Department of Physics, Tohoku University, Sendai, Japan. High-energy reactions of elementary particles. Came to Argonne on 30 July 1963. (Host: M. Peshkin.)

Dr. Harry J. Lipkin, Professor of Physics, Weizmann Institute of Science, Rehovoth, Israel. Unitary symmetry of elementary particles; simple models of many-particle systems. Returned to Argonne on 3 June 1963. (Host: M. Peshkin.)

Dr. Karl-Edvard Nystén, Research Associate, University of Helsinki, Finland. Study of (p,γ) reactions at the Van de Graaff accelerator. Came to Argonne on 1 July 1963. (Host: R. E. Holland.)

Dr. Sudhir Pandya, Associate Professor, Physical Research Laboratory, Ahmedabad, India. Theoretical nuclear spectroscopy. Came to Argonne on 22 July 1963. (Host: M. Peshkin.)

Resident Research Associates (Summer)

Dr. Akito Arima, Lecturer in Department of Physics, University of Tokyo. Theory of nuclear structure. Returned to Argonne on 11 June 1963. (Host: M. Peshkin.)

Dr. Louis A. P. Balázs, School of Mathematics, Institute for Advanced Study, Princeton, New Jersey. Bootstrap mechanism of coupled $\pi\pi$-$\pi\omega$ processes. Came to Argonne on 22 July 1963. (Host: M. Peshkin.)

Dr. George B. Beard, Associate Professor of Physics, Wayne State University. Nuclear resonant fluorescent scattering of gamma rays. Came to Argonne on 17 June 1963. (Host: L. M. Bollinger.)

Dr. Raymon T. Carpenter, Assistant Professor of Physics, State University of Iowa. Slow-neutron physics on the fast chopper; resonance-capture gamma-ray spectra. Returned to Argonne on 17 June 1963. (Host: L. M. Bollinger.)

Dr. Justo A. Diaz, Assistant Professor of Physics, Ottawa University. Mössbauer effect in Cs^{133} and I^{129}. Came to Argonne on 5 June 1963. (Host: J. Heberle.)

Dr. Patrick D. Doherty, Alma College, Los Gatos, California. Spatial asymmetries in the decay of polarized neutrons. Came to Argonne on 3 June 1963. (Host: G. R. Ringo.)

Dr. Richard A. Ferrell, Professor of Physics, University of Maryland. Collective enhancement of M1 nuclear transitions. Came to Argonne on 17 June 1963. (Host: M. Peshkin.)

Dr. Anthony M. Green, Research Associate, University of Maryland, College Park. Low-energy nuclear physics and the many-body problem. Came to Argonne on 17 June 1963. (Host: M. Peshkin.)

Dr. Mazhar Hasan, Associate Professor of Physics, Northern Illinois University. Theory of plasma admittance in a high-frequency discharge. Came to Argonne on 13 June 1963. (Host: A. J. Hatch.)

Dr. Amnon Katz, Senior scientist, Weizmann Institute, Rehovoth, Israel. Many-body problem. Came to Argonne on 3 July 1963. (Host: M. Peshkin.)

Dr. Behram Kursunoglu, Professor of Physics, University of Miami. Nuclear and Coulomb scattering in strong magnetic field. Came to Argonne on 12 June 1963. (Host: M. Peshkin.)

Dr. Smio Tani, Research Scientist, New York University. Convergence of Born series in potential scattering. Came to Argonne on 2 July 1963. (Host: M. Peshkin.)

Resident Research Associate (Post-Doctoral)

Dr. Amnon Marinov. Charged-particle reactions and elastic scattering. Came to Argonne on 5 June 1963. (Host: J. P. Schiffer.)

Resident Student Associate (Summer)

Mr. S. V. Paranjape, graduate student, Illinois Institute of Technology. Working through the Association of Midwest Universities with A. J. Hatch on measurement of the properties of rf plasmas. Came to Argonne on 22 May 1963.

Resident Student Associate (Thesis)

Mr. William C. Johnston, graduate student, Western Michigan University, Kalamazoo. Working with S. B. Burson on angular correlation experiments. Came to Argonne on 17 June 1963.

Student Aides (Summer)

Mr. William B. Ashworth, Wesleyan University, Middletown, Connecticut. Working with L. Meyer-Schützmeister on analysis of data on the $K^{39}(p,\alpha)$ and $C^{12}(d,\alpha)$ reactions. Came to ANL on 13 June 1963.

Mr. Edward Chase, Manchester College, Manchester, Indiana. Working with Manfred Kaminsky on assembly and testing of the pulsed-beam mass spectrometer. Came to ANL on 4 June 1963.

Mr. Michael Crisp, Bradley University, Peoria, Illinois. Working with R. K. Smither on processing of data from the bent-crystal spectrometer. Came to ANL on 4 June 1963.

Mr. William S. Denno, Kalamazoo College, Kalamazoo, Michigan. Working with S. S. Hanna on Mössbauer analyses of meteorites and ferromagnetic alloys. Returned to ANL on 18 June 1963.

Mr. Gary Feldman, University of Chicago. Working with John Erskine on taking and analyzing magnetic-spectrograph data. Came to ANL on 18 June 1963.

Mr. William R. Gage, Carleton College, Northfield, Minnesota. Working with Ralph Segel on analysis of data on the $B^{11}(p,\gamma)C^{12}$ reaction. Came to ANL on 13 June 1963.

Miss Carol L. Hagaman, Western Illinois University, Macomb. Working with C. C. Trail on analysis of γ-ray spectra from the reaction $F^{19}(p,\alpha\gamma)O^{16}$. Came to ANL on 13 June 1963.

Mr. Robert L. Johnson, St. Olaf College, Northfield, Minnesota. Working with W. A. Chupka and J. Berkowitz on measurements of ionization cross sections. Came to ANL on 13 June 1963.

Miss Sharon L. Kromer, Michigan State University, East Lansing, Michigan. Working with R. E. Coté on analysis of data taken with the fast chopper. Came to ANL on 11 June 1963.

Miss Janet L. Mather, University of Chicago. Working with S. B. Burson on computer programs for spectrum analysis; decay scheme of W^{188}. Came to ANL on 18 June 1963.

Mr. Lewis Milton, University of Illinois. Working with J. L. Yntema on analysis of data from the 60-in. scattering chambers. Came to ANL on 18 June 1963.

Mr. David Patterson, Grinnell College, Grinnell, Iowa. Working with J. P. Schiffer on calculations of charge distributions and energy levels in nuclei. Came to ANL on 6 June 1963.

Mr. Melvin Pronga, Monmouth College, Monmouth, Illinois. Working with D. S. Gemmell on assisting in collection and analysis of data on the $Li^6(\alpha,\alpha)$ reaction. Returned to ANL on 2 July 1963.

Mr. Richard W. Reno, Knox College, Galesburg, Illinois. Working with J. Heberle on experiments with the Mössbauer effect. Returned to ANL on 5 June 1963.

Mr. George Rieke, Oberlin College, Oberlin, Ohio. Working with G. J. Perlow on Mössbauer experiments and analysis of the data. Returned to ANL on 11 June 1963.

Co-op Technicians

Mr. Timothy Lawler III, Marquette University, Milwaukee, Wisconsin. Working with J. P. Schiffer on reduction of the data from reaction and elastic-scattering experiments. Came to ANL on 3 June 1963.

Mr. Charles Denis Pruett, Purdue University, Lafayette, Indiana. Working with L. Meyer-Schützmeister on analysis of data on the $C^{12}(d,\alpha)$ and $B^{10}(p,\gamma)$ reactions. Came to ANL on 10 June 1963.

Technicians

Mr. Warren T. Jivery joined the Physics Division on 6 June 1963 as a Research Technician (Junior) to work with W. A. Chupka and J. Berkowitz.

Mr. Manley S. Keeler returned to the Physics Division for the summer on 12 June 1963 as a Research Technician (Junior) to work with R. Amrein.

Mr. Edward J. Leech joined the Physics Division on 13 August 1963 as a Research Technician (Junior) to work with J. R. Wallace.

Mr. James Pasteris joined the Physics Division on 22 July 1963 as a Research Technician (Junior) to work with William Evans.

Clerk

Miss Janet Harris joined the Physics Division on 15 July 1963 to work with R. E. Segel.

PROMOTIONS

Mr. Arthur E. Froehlich has been promoted from Research Technician to Senior Technician.

Mr. David Lee Kurth has been promoted from tracer to detailer.

DEPARTURES

Dr. Howard W. Broek who has been a staff member of the Physics Division since 1960 terminated on 7 June 1963 to go to the Bell Telephone Laboratories, Whippany, New Jersey, to work on acoustical oceanography.

Dr. Stanley S. Hanna, who has been on the staff of the ANL Physics Division since September 1955, has worked at the Van de Graaff and Tandem accelerators on the excited states of light nuclei (Project I-21), on positron polarization resulting from the failure of parity conservation in weak interactions (Project I-125), and on the nuclear resonant absorption of gamma rays (Project I-19) which in recent years has consisted largely of Mössbauer studies. He terminated at ANL on 20 August 1963 to become Professor of Physics at Stanford University, Stanford, California.

Dr. Michitoshi Soga, who has been a Resident Research Associate at Argonne since 21 August 1961 terminated 5 August 1963.

Transfer

Dr. Sol Wexler transferred from Physics to the Chemistry Division on 1 July 1963.